Optical Oceanography at the Darling Marine Center

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LONG-TERM GOALS

The long-term goal of this program is to train a cadre of students in environmental optics and to provide them with a broad perspective of the field. Our goal is not just to educate optical oceanographers but also to foster integration of optical approaches into oceanographic research in general. The Optical Oceanography course, which has been offered a number of times since 1985, creates an environment in which students collaboratively learn theory, measurement, and models of optical oceanography and remote sensing.

OBJECTIVES

The objectives of the Optical Oceanography course are to create an opportunity for graduate students and recent post-doctoral fellows from diverse disciplines to interact with senior researchers in optical oceanography and to learn the fundamentals – theory, measurement, and models – of optics and remote sensing in a coastal/estuarine environment. The course creates a learning environment in which graduate students can integrate optics, remote sensing, and oceanography and it provides them with a forum for discourse on and analysis of new directions in optics.

APPROACH

The five-week graduate course in Optical Oceanography was held the University of Maine’s Darling Marine Center between 15 July and 18 August 2001. The course integrated optical theory, in-water and above-water measurements, and models. Field measurements, made by the students, were incorporated into the HYDROLIGHT optical model and used as teaching tools to explore the errors and limitations of both. The close proximity of a diversity of coastal/estuarine water types enabled the students to develop an appreciation for the special research issues associated with Case II waters. Integration of in-water and above-water remote sensing measurements provided students with an appreciation of the power, complexity and limits of remote-sensing programs.

The main elements of the course were: (1) formal lectures; (2) formal laboratory sessions and field campaigns wherein student learned state-of-the-art measurement and analysis for absorption, scattering, fluorescence, and remote sensing; (3) modeling exercises, including HYDROLIGHT and Mie models, with an emphasis on closure and integration of measurements with models and theory;

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14. ABSTRACT
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15. SUBJECT TERMS

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(4) guest lectures; (5) group discussions of key papers; and (6) student projects, wherein the student investigated a specific, focused question and concluded the project with oral and web reports.

Course instructors included:

Dr. Emmanuel Boss, Oregon State University
Dr. Kendall Carder, University of South Florida
Dr. Curtis Mobley, Sequoia Scientific, Inc.
Dr. Mary Jane Perry, University of Maine
Dr. Collin Roesler, Bigelow Laboratory for Ocean Sciences

Guest lecturers included:

Dr. William Balch, Bigelow Laboratory for Ocean Sciences
Dr. Joan Cleveland, Office of Naval Research
Dr. Charles Eriksen, University of Washington
Dr. Larry Harding, University of Maryland's Horn Point Laboratory
Dr. Sara Lindsay, University of Maine
Dr. David Martin, Ocean.US
Dr. John Morrow, Biospherical Instruments, Inc.
Dr. Richard Spinrad, Technical Director, Oceanographer of the Navy
Dr. Michael Twardowski, WET Labs, Inc.
Dr. Charles Yentsch, Bigelow Laboratory for Ocean Sciences

WORK COMPLETED

Formal lectures included:

Lecture 1: Light and Radiometry
Lecture 2: Introduction to IOPs, AOPs and radiative transfer equation/RTE
Lecture 3: IOPs: Absorption; overview of ocean absorbers
Lecture 4: IOPs: Theory of absorption measurement
Lecture 5: IOPs: : CDOM and Detritus
Lecture 6 Pigments and photoadaptation
Lecture 7: IOPs: Scattering: definitions and measurement methods
Lecture 8: IOPs: Particles in the ocean
Lecture 9: Relationship between particles and scattering
Lecture 10: RTE derivation/overview
Lecture 11: AOPs: Introduction
Lecture 12: Introduction to remote sensing
Lecture 13: Hydrolight
Lecture 14: Ocean color satellite remote sensing
Lecture 15: Single-particle IOPs & efficiency factors
Lecture 16: Shallow water remote sensing
Lecture 17: Analytic solutions for forward prediction of RTE
Lecture 18: Radiometric calibration issues
Lecture 19: Atmospheric corrections for remote sensing
Lecture 20: Remote sensing reflectance inverse models
Lecture 21: Aircraft remote sensing

Lecture 22: Models for IOPs
Lecture 23: Raman and fluorescence as sources
Lecture 24: ONR goals and future directions
Lecture 25: Bidirectional reflectance
Lecture 26: Remote sensing reflectance in local waters
Lecture 27: Photosynthesis and light
Lecture 28: New scattering instruments and calibration
Lecture 29: Optical properties of coccolithophores
Lecture 30: Optical methods for enabling in situ measurement of dissolved chemicals
Lecture 31: Bioluminescence
Lecture 32: Chlorophyll fluorescence to quantify primary productivity
Lecture 33: Data statistics and least square modeling
Lecture 34: What is Naval Oceanography
Lecture 35: National Ocean Observing System
Lecture 36: History of productivity models
Lecture 37: Underwater visibility and imaging
Lecture 38: IOPs - Scattering spectrum; inversion of IOPs
Lecture 39: Lidar remote sensing
Lecture 40: Polarization

Formal laboratory sessions included:

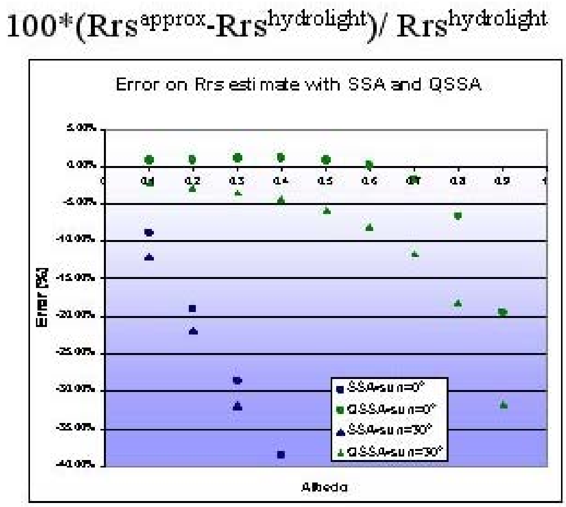
Laboratory 1: Playing with light
Laboratory 2: Transmissometer Lab
Laboratory 3: Radiance and Irradiance
Laboratory 4: Absorption: ac-9
Laboratory 5: Absorption: spectrophotometry
Laboratory 6: Fluorescence
Laboratory 7: Total Scattering
Laboratory 8: Backscattering
Laboratory 9: Remote Sensing Reflectance
Laboratory 10: Particle Size Distribution:
Laboratory 11: Visible Radiance and Irradiance
Laboratory 12: UV Radiance and Irradiance
Laboratory 13: HYDROLIGHT model
Laboratory 14: Mie scattering models

RESULTS

Twenty students from a diverse range of institutions participated in the Optical Oceanography course. The Power Point presentations from the student are available via a web from a link from http://www.ume.maine.edu/~marine/perry.htm

One example is from Mr. Simon Bellanger's project in which he compared the performance of the HDRYOLIGHT model with the single and quasi-single scattering approximation solutions (SSA, QSSA) of the radiative tranfer equation (RTE). He modeled remote sensing reflectance (RRS) using

input from IOPs measured with the ac-9 and Hydroscat. The modeled results were compared with the actual measured remote sensing reflectance (RRS) in the Damariscotta River Estuary.



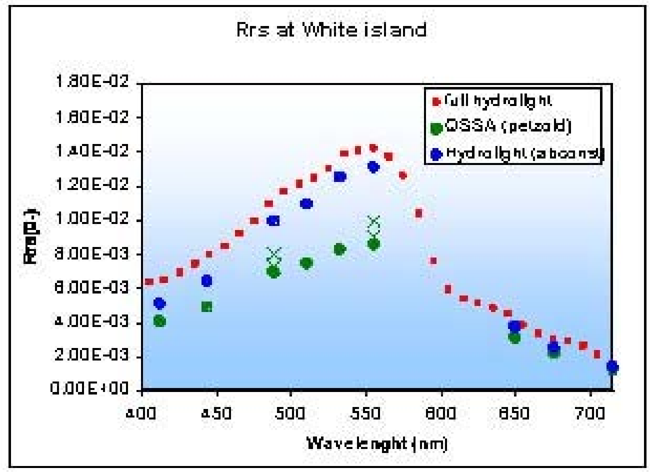


Figure 1. An analysis of error demonstrated that, compared to HDRYOLIGHT results, the QSSA method was less sensitive to changes in water albedo than SSA. Modeled RRS for showed that SSA was relatively insensitive to solar angle, although the QSSA did show some solar angle sensitivity.

Figure 2. These modeling results were compared to the actual RRS measured. The QSSA results compared most favorably to the measured RRS; HYDROLIGHT results tended to over-estimate RRS, particularly in the blue-green, even with a non-Petzold phase function.

IMPACT/APPLICATIONS

The training that these students obtain during the five-week intensive course is making a major contribution to their graduate and post-graduate careers.

TRANSITIONS

Since 1985, over 85 students have taken the Optical Oceanography course (either at Friday Harbor or at the Darling Marine Center). This interactive training is producing a generation of geoscientists who include optics as a tool in their pursuit of understanding the oceans. This course has helped to transition knowledge of ocean optics more rapidly into ocean sciences in general.

REFERENCES

Culver, M. E., and M. J. Perry. 1997. Calculation of solar-induced fluorescence from surface and subsurface waters. *Journal of Geophysical Research* **102:** 10,563-10,572.

Culver, M. E., and M. J. Perry. 1999. Fluorescence excitation estimates of photosynthetic absorption coefficients for phytoplankton and their response to irradiance. *Limnology and Oceanography* **44:** 24-36.